Original research paper

Estimation of Stature from Measurements of Long Bones, Hand and Foot Dimensions

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Abstract

Estimation of stature holds a special place in the field of Forensic anthropometry. The present study is an attempt to evaluate a possible correlation between stature of an individual & six parameters; hand-length, hand-width, foot-length, foot-width, forearm length & knee-to-ankle length individually in a local population of Mumbai. A sample of 300 medical students; 147 male & 153 female studying in Grant Medical College & Sir JJ Group of Hospitals was considered & measurements were taken for each of the parameters. It was found that all the six parameters showed a correlation with stature but at different degrees (significance calculated through the paired t-test). Forearm-length showed the highest degree of correlation ($r = 0.6558$) followed by foot-length ($r = 0.6102$). Knee-to-ankle length showed the lowest degree of correlation ($r = 0.2086$). Mathematical formulae for estimating stature were developed for each of these parameters through basic linear regression. It can be concluded that the present study has provided regression equations for six different parameters that can be used for stature estimation in the population of Mumbai. These equations should not be used for other Indian population groups.

Key Words: Height, Stature, Hand-Length, Hand-Width, Foot-Length, Foot-Width, Forearm-Length, Knee-Ankle Length

Introduction:

Estimation of stature has a significant importance in the field of forensic anthropometry. Establishing the identity of an individual from mutilated, decomposed, & amputed body fragments has become an important necessity in recent times due to natural disasters like earthquakes, tsunamis, cyclones, floods and man-made disasters like terror attacks, bomb blasts, mass accidents, wars, plane crashes etc. It is important both for legal & humanitarian reasons. ‘Stature’ is one of the most important elements in the identification of an individual.

Many different body parts can be used in the estimation of stature. Certain long bones & appendages can be aptly used in the calculation of height of a person. Many studies have shown the correlation of stature with body appendages [1-9] & with long bones [10-19]. But there are inter-racial & inter-geographical differences in measurements & their correlation with stature. What may be true for one race or one region may not be true for the other.

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Even within our vast homeland of India there are many different ethnic populations & they having their own variations. [1, 2, 6-13, 18, 19] The lack of anthropometric data concerning the local population of Mumbai was felt as the city is prone to disasters like the terror attacks on 26th November 2008.Hence the present study was aimed at & concentrated on the Indian population of Mumbai of known stature of which anthropometric measurements of upper limb & lower limb were calculated & correlated with stature to find multiplication factors & regression formulae. Study was carried out at Department of Forensic Medicine & Toxicology, Grant Medical College & Sir JJ Group of Hospitals, Mumbai.

Materials & Methods:

The study was a cross-sectional one with 300 subjects in the age group of 19 to 23 years, with 147 males & 153 females. The procedure, aims & objectives of the study were informed & explained in a group. A written valid informed consent was taken from each of the participants. A small group of ten students were taken for measurements each day at a fixed time to avoid diurnal variations. The students were measured for the following parameters:

- **Weight**: Using an electronic weighing machine.
- **Height**: Standard anthropometric measuring instruments.
- **Forearm Length**: From tip of olecranon process to mid-point joining radial & ulnar
tuberosity using a standard measuring tape (Position: Arm-Flexed).

- **Hand-Width**: From base of 5th to 2nd metacarpal using a standard vernier calliper (Position: Prone).
- **Hand-Length**: From mid-point below radial & ulnar tuberosity to tip of middle finger using a standard measuring tape (Position: Supine).
- **Foot Length**: From tip of toe to heel on the medial side using a standard measuring tape (Position: Standing).
- **Foot Width**: From base of 1st to 5th metatarsal using standard vernier calliper (Position: Standing)
- **Knee to Ankle**: From mid-point below radial & ulnar tuberosity to tip of middle finger using a standard measuring tape (Position: Sitting, knee flexed).

**Statistical Analysis:**

The primary outcome was the regression equation for each parameter. Correlation coefficient (-1 to +1) was calculated for each parameter as were range, mean and standard deviation. We analysed our data using SPSS (version 16.0.2) & calculated significance via the paired t-test.

**Results:**

The results are given below in the table after the statistical analysis. (Table-1)

**Regression Equations:**

The regression equations derived for each of the parameters are as follows:

**Estimation of stature from hand-length:**

- \( Y = 116.892872 + 2.665389 \times X \) (Y: Stature of individual, X: Hand-length)

**Estimation of stature from hand-width:**

- \( Y = 113.561732 + 7.139216 \times X \) (Y: Stature of individual, X: Hand-width)

**Estimation of stature from Foot-length:**

- \( Y = 79.72379 + 3.650632 \times X \) (Y: Stature of individual, X: Foot-length)

**Estimation of stature from Foot-width:**

- \( Y = 114.828119 + 5.906901 \times X \) (Y: Stature of individual, X: Foot-width)

**Estimation of stature from Forearm- Length:**

- \( Y = 86.772654 + 2.997967 \times X \) (Y: Stature of individual, X: Forearm Length)

**Estimation of stature from Knee-to-ankle length:**

- \( Y = 156.543454 + 0.296018 \times X \) (Y: Stature of individual, X: Knee-to-ankle length)

**Discussion:**

In a study done by Bhavna & Surinder Nath concerning estimation of stature based on lower limb measurements on 503 Shia Muslims in the age group of 20-40 years of New Delhi, the Tibial Length was found to be the best estimate of stature [13]. In the present study, among the lower extremity measurements foot-length\((r=0.6102)\) was found to be the best estimate of stature. Also, knee-to-ankle length correlated poorly with stature\((r=0.2086)\) contrary to the findings in the above mentioned study.

A study based on the measurements of foot length and body height of total 502 students between 17 to 22 years of age was done by Patel Shah et al [2]. They had found that foot-length showed a high degree of correlation with height of the individual. The present study also highlights a strong correlation between height & foot-length \((r = 0.6102)\).

A study was done to examine the relationship between stature and dimensions of hands and feet among Rajputs of Himachal Pradesh - a North Indian endogamous group done by Krishnan et al [6]. Hand length, hand breadth, foot length and foot breadth of 246 subjects were considered & it was found that foot-length was the best measure of estimating stature of an individual. In our study, among the hand & feet measurements, hand-width \((r = 0.6004)\) was found to be the best estimate of stature. Studies by Agnihotri A, Purwar B[9] ; Sen J, Ghosh S[7] ; Kanchan T, Menezes RG[20] et al. had similar conclusions to the present study.

A study by Athawle et al. on one hundred Maharashtrian male adults of ages between 25 to 30 years, showed that height could be reliably estimated from forearm length. The present study also showed similar results.

The present study highlights that hand-length, hand-width, forearm length foot-length & foot-width can be reliably used for estimation of stature in the region of Mumbai. Of all the parameters, forearm length showed the highest degree of correlation \((r = 0.6558)\) followed by foot-length \((r = 0.6001)\). Knee-to-ankle length showed the least correlation \((r = 0.2086)\). It would not be wise to apply the same data on other Indian population groups.

**Limitations:**

1. In the present study, age range of only 19 to 23 years is considered.
2. Measurements of only healthy individuals are considered. Hence the data may not be applicable to individuals who are malnourished &/or suffering from congenital structural malformations.
3. Sex variation is not taken into consideration.
4. Applicability of anthropometric measurements in living & deceased individuals may practically differ.
5. The present study is a preliminary one & would be followed up by other studies to address the above limitations.
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The estimation of adult stature from limb measurements among people of different region & race. Hence there is a need to conduct more studies among people of different regions & ethnicity so that stature estimation becomes more reliable & identity of an individual is easily established.

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References:

Table 1
Range, Standard Deviation (SD), Correlation Coefficient(r) & Regression coefficient(b) values of the Anthropometric Measurements

<table>
<thead>
<tr>
<th>Parameters Assessed</th>
<th>Range (in cm)</th>
<th>Mean ±SD</th>
<th>R</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height</td>
<td>138-186</td>
<td>167.265 ± 8.494</td>
<td>0.5902</td>
<td>2.6654</td>
</tr>
<tr>
<td>Hand-Length</td>
<td>11.50-27</td>
<td>18.938 ± 1.88</td>
<td>0.6048</td>
<td>7.1392</td>
</tr>
<tr>
<td>Hand-Width</td>
<td>5.80-8.90</td>
<td>7.537 ± 0.714</td>
<td>0.6004</td>
<td>7.1392</td>
</tr>
<tr>
<td>Foot-Length</td>
<td>20.85-28</td>
<td>24.008 ± 1.420</td>
<td>0.6102</td>
<td>3.6506</td>
</tr>
<tr>
<td>Foot-Width</td>
<td>7.10-10.05</td>
<td>8.895 ± 0.703</td>
<td>0.4886</td>
<td>5.9069</td>
</tr>
<tr>
<td>Forearm-length</td>
<td>23-31.20</td>
<td>26.884 ± 1.866</td>
<td>0.6588</td>
<td>2.9980</td>
</tr>
<tr>
<td>Knee-to-ankle length</td>
<td>20.50-85.05</td>
<td>36.574 ± 5.984</td>
<td>0.2086</td>
<td>0.2960</td>
</tr>
</tbody>
</table>